Renovation of horticultural waste into organic fertiliser by vermicomposting technology: approach for solid waste management

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Abstract: Horticulture products which are produced in Cuddalore district of Tamilnadu have unique demand all over India. The production of horticultural products leads to enormous amount of horticultural wastes. Wastes recycling can bring tremendous benefits to agriculture and land management in long run. On the other hand vermicompost and vermiwash can be used for all crops as bio-fertilisers. Vermicomposting can be used for solid waste management and the production of bio-fertilisers. The aim of this study is to utilise these waste for the production of vermicompost using *Eisenia fetida* and *Eudrillus Eugenia* after mixing with cow dung and soil. Vermicomposting is performed for the period of 85 days and physicochemical analysis showed decreased in TOC, TOM and C: N and increased in NPK content. The results show that vermicompost produced by *E.fetida* possesses higher nutrient contents than that of *E.Eugenia* and can be used for effective production of vermicompost using horticultural wastes.

Keywords: horticultural waste; earthworm; cow dung; vermicomposting technology; vermiwash; organic fertiliser; nutrient recycling; plant growth.

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1 Introduction

Cuddalore district of Tamilnadu state is one of the leading producer of horticultural products in India. This abundance of raw materials is causing major problems in the disposal of the waste. The practice of vermicompost is at least a century old but it is now being received worldwide attention with diverse ecological objectives such as waste management, soil detoxification, renewal and sustainable agriculture. Vermicomposting is the bio-conversion of organic waste into solid and liquid bio fertilisers through the earthworms gut which act as the bio-reactor (Manyuchi and Whingiri, 2014). The non-burrowing earthworms eat 10% soil and 90% organic waste materials; these convert the organic waste into vermicompost faster than the burrowing earthworms (Kamineni and Sidagam, 2014). Vermicomposting is a simple bio-technological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better product (Adhikary, 2012). Selection of earthworm species is an important factor because only few species are able to survive and adjust to a particular type of environment. The exotic earthworm species namely *Eisenia fetida* and *Eudrilus Eugenia* are commonly used for breaking down the organic waste. The earthworms being voracious eaters and consume the biodegradable matter and give out a part of the matter as excreta or vermi-castings. Such technologies in organic waste management would lead to zero waste techno farms without the organic waste being wasted and burned rather than would result in recycling and re-utilisation of precious organic waste bringing about bio conservation and bio vitalisation of natural resources (Nagalakshmi et al., 2016). Vermicompost, a very potential organic input for agriculture, contains beneficial microorganisms, both major (N, P, K) and micro nutrients, enzymes and hormones. The most efficient species of earthworm for Vermicomposting by comparing the performance of different species of earthworms on composting of organic wastes (Rajendran and Thivyatharsan, 2014). The partially decomposed sunflower cob alone may be used for the production of vermicompost by using three earthworm species namely *Eudrilus Eugenia*, *Perionyx excavatus* and *Lampito mauritii* and they may be used to produce vermicompost and in particular L. mauritii is very effective (Viji and Neelanarayanan, 2016). Vermicompost contains enzymes like amylase, lipase, cellulase and chitinase, which continue to break down organic matter in the soil (to release the nutrients and make it available to the plant roots). The present study is therefore aimed at utilising Horticultural wastes along with cow dung and soil for the preparation of vermicompost using *Eudrilus Eugenia* and *Eisenia fetida* earthworms and also to monitor the pH, electrical conductivity (EC), total organic carbon (TOC), total organic matter (TOM), total Kjeldahl nitrogen (N2), carbon to nitrogen (C: N) ratio along with the bacterial population of the resultant composts.

2 Methods

2.1 Collection of waste and earthworm

Horticultural debris are collected from landscape maintenance contractors. The people of the district do not collect waste that has been cut by private contractors. Now a day's private contractor sold out the waste to the nearby village farmers. Almost in Virudhachalam Taluk in Cuddalore District many farmers are preparing vermicompost with the help of training programmes conducted by TNAU-KVK (Tamil Nadu Agricultural University-Krishi Vigyan Kendra) Virudhachalam and achieving successful entrepreneurs. About 20 metric tons (MT) waste from horticulture generated in the Cuddalore district also ends up dumped unprocessed at the already overflowing landfill. The biomass decomposes gradually thereby steadily releasing nutrients to the soil. *E.Eugenia* and *E.Fetida* were collected from TNAU vermiform in Virudhachalam taluk at Cuddalore district.

2.2 Experimental procedure

Horticultural wastes (60 kg of half decomposed waste), 110 kg of fresh cow dung and two different earthworm species were used for the waste degradation process.

Table 1 Different kinds of waste preparation includes

	Waste preparation methods
(A1)	Horticulture waste + cow dung + soil (Control)
(A2)	Horticulture waste + cow dung + soil+ Earthworm (E.Eugenia)
(A3)	Horticulture waste + cow dung + soil+ Earthworm (E.Fetida)

The first set of experiment was carried without earthworm as control. The second and third set of experiment were undertaken to study the role of *Eudrilus Eugenia* (1 kg) and *Eisenia fetida* (1kg) respectively on the quality of vermicompost produced (Arumugam et al., 2015). This is studied in terms of various parameters such as pH, EC, moisture content, TOC, N2 and C: N ratio (Biglari et al., 2016). The effects of vermicompost and vermiwash on various plants (Jain, 2016) have been studied. Vermicompost and vermiwash influence on plants such as maize (Abawari, 2016) and cashew graft has been examined. For maize several of the factors such as growth, reproductive organs, formation of new maize, colour and texture of leaves and for cashew graft some of the parameters such as number of leaves, shoot height, shoot dry matter was used to measure of the effectiveness of the vermi-products.

2.3 Vermicomposting process

Three chambers with dimension of 5 cm length, 1.5m width and 1.5 m height were constructed for the preparation of compost. The chamber was covered by jute bags (Viji and Neelanarayanan, 2016). One layer of Horticulture waste was spread over the ground in the chamber followed by soil and then the cow dung slurry equal to 20% weight of biomass was sprinkled. The chambers were labeled as A1, A2 and A3. The mixtures were turned over manually everyday for 15 days in order to eliminate volatile substances that are toxic to the earthworms. After 15 days, 1 kg of *E.Eugenia* earthworms were introduced into the second containers named as A2 and *E.Fetida* introduced into the third container named as A3. The moisture content was maintained at 60–76% throughout the study period by periodic sprinkling of adequate quantities of water (Maya and Bhalerao, 2016). Stop watering before one week of harvest. Heap the compost and the material was sieved using 3 mm sieve, the material passed through the sieve is called as vermicompost which was stored in a polythene bags. Cocoons are collected after sieving. Re composting is done in the same pit or bed. Similarly the above process may be done repeatedly. For draining of vermiwash an opening (Maheswari and Ilakkiya, 2015) was provided which was connected to a tank with PVC pipes in order to use the vermiwash can be utilised as liquid manure. After twelfth weeks the samples were taken and analysed.

2.4 Physico-chemical analysis

The pH and EC of samples were recorded by a digital pH metre and conductivity metre, respectively (Vinothini et al., 2016). These values were recorded continuously throughout the experimental period. Total N2 was estimated by the Kjeldahl method (Jackson, 1973). Total organic carbon was measured by the method of Nelson and Sommer (1996). Total potassium was determined by flame photometer. Total phosphorus was analysed using the calorimeter method (Anderson and Ingram, 1993).

3 Results

Earthworms play an important role in maintaining soil fertility through Vermicomposting. In the present study the vermicompost prepared was dark black granular in appearance (Figure 5) which indicated that the decomposition of Horticultural waste occurred successfully (Figures 2, 3 and 4), as the earthworms consume Horticultural wastes organic matter very rapidly and fragment them into finer particles, by passing them through a grinding gizzard. The yield of vermicompost was calculated and recorded individually. In the present study, pH has increased from 7.5 in A1 and 8.5 in A3. This pH increase to alkaline in the end product confirms the release of ammonia from the nitrogenous compounds followed by the completion of the process (Figure 6). Increase in EC from A1 to A3 due to loss of organic matter and release of different mineral salts in available forms are such as phosphate, ammonium, and potassium ions (Table 1). There was a noticeable reduction in the TOC and TOM in the final vermicompost prepared from waste using *E.Eugenia* and *E.Fetida* which is due to the microbial respiration. The N2 content percentage increase might instigate from the addition of nitrogen through the earthworm itself in the form of mucus, nitrogenous excretory substance, growth stimulating hormones and enzymes. Phosphorus increased by the closing stages of the process owed to the mineralisation of organic matter (Kapoor et al., 2015). Increase in K possibly due to the direct action of earthworm guts and indirectly by the simulation of micro flora. Moreover, the Increase in earthworm population might also be attributed to the C: N ratio decreasing with time. Decline of C: N ratio to less than 20 indicates an advanced degree of organic matter stabilisation and reflects a satisfactory degree of maturity of organic waste. The study shows that the nutrient concentrations of *Eisenia fetida* is high compared to *Eudrilus Eugenia*. From these results, it can be concluded that the *Eisenia fetida* is more efficient species in vermicomposting.

Figure 1 Whole experimental unit

Figure 2 Research area

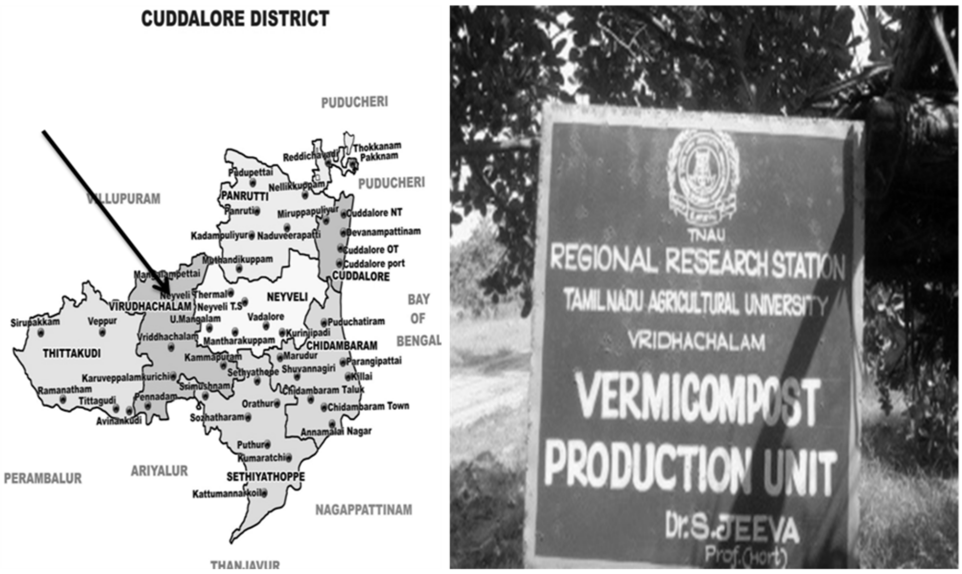


Figure 3 Collection of horticultural waste

Figure 4 Vermipit with horticultural waste

Figure 5 Top view of horticultural waste after 35 days

Figure 6 Top view of horticultural waste after 86 days

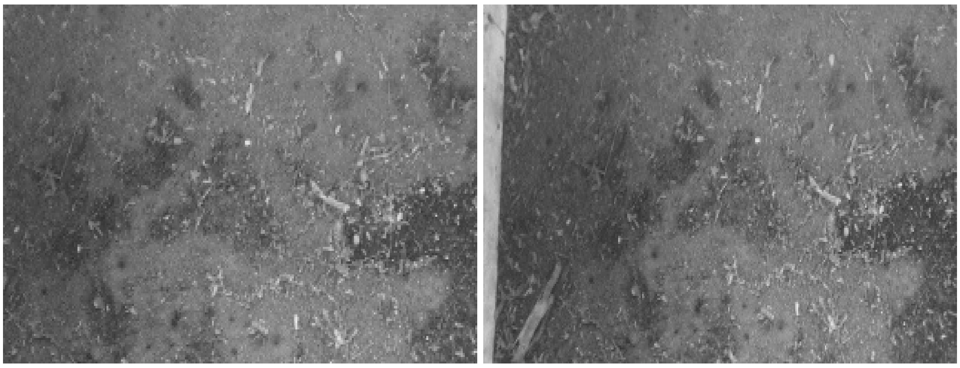
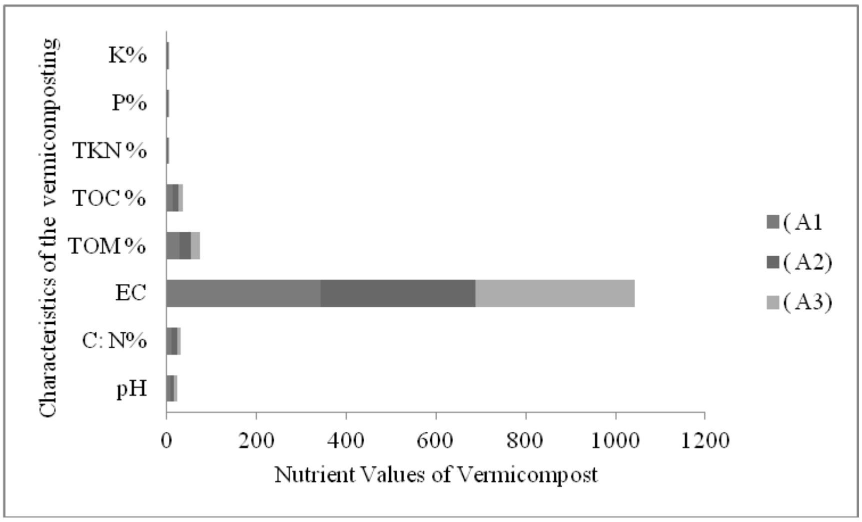


Figure 7 VC sieved through 3 mm mesh after sieving

Figure 8 Nutrient values of vermicompost



3.1 Vermiwash

Vermiwash is a leach ate that is produced during the Vermicomposting process and it is dark brown in colour. It is a collection of excretory and secretory products of earthworms, along with major micro nutrients of the soil and soil organic molecules that are useful for plants. It is applied as foliar spray. This is transported to the leaf, shoots and other parts of the plants in the natural ecosystem. It contains various enzymes cocktail of protease, amylase, unease and phosphates. These are beneficial for growth and development of plants and stimulate the yield and productivity of crops. The microbial study of vermiwash found that nitrogen fixing bacteria like Azotobacter, Agro bacterium, Rhizobium and some phosphates solublising bacteria are also found in vermiwash. The nutritional composition of vermiwash obtained from horticulture waste in terms of NPK and trace elements composition is summarised in Table 2.

Table 2 Characteristics of the vermicomposting on 12th weeks of composting was done

Types of waste	*pH*	*C: N%*	*Electrical conductivity (EC) µS/cm*	*TOM %*	*TOC %*	*TN %*	*P%*	*K%*
(A1) – control	7.5	11.5	342	27.7	12.6	1.2	1.01	0.007
(A2)	7.6	10.6	346	25.2	12	1.4	1.06	0.12
(A3)	8.5	9.2	354	20.4	11.9	1.6	1.08	0.18

Table 3 Nutrient values of vermiwash

Types of waste	*N %*	*P%*	*K%*
(A1) – control	1.3	7.2	1.1
(A2)	1.5	7.5	1.2
(A3)	1.6	7.6	1.3

3.2 Benefits of vermiwash an effective biopesticide

Vermiwash acts as a plant tonic and helps to reduce many plant diseases. A mixture of vermiwash (1 litre) with cow urine (1litre) in 10 liters of water acts as Biopesticide and liquid manure.

3.3 Application of vermicompost and vermiwash to crops

Vermicompost can be used for all crops such as agricultural, horticultural and vegetable etc. But generally, vermicompost is recommended for high value vegetables and fruit crops. Application need to be done around root zone in the opened ring and covered by the soil.

3.3.1 Application In cashew orchards

Cashew is propagated by both seeds and also by vegetative methods. Seed propagation results in enormous variability in the seedling progeny. Therefore, high yielding cashew varieties are commercially propagated by different vegetative methods to produce two type planting material, which is described below. Before grafting, the cashew is grown in a glasshouse maintained at 22°C. Plants was grafted when seedlings were six weeks old after germination. Soft wood grafting: This is the most popular and the best method for commercial multiplication of improved cashew varieties and found to be suitable for propagation almost round the year. However, higher success rate of grafting can be achieved during the month of June to December due to abundance of mature scion shoots, favourable temperature and higher relative humidity conditions. Rising of root stock: Potting mixture in the proportion of one part of red soil: one part of sand: one part of compost has to be prepared (40–50 g) added to it (vermicompost collected from *E.Fetida*). This is filled in high density polythene bags of 25 cm × 15 cm size having thickness of 250-300 gauges, with holes punched on them for proper drainage for raising the root stock seedlings. Field observations were made (Figures 9 and 10) and data collected on, height of graft shoot, number of shoot leaves, and shoot dry matter yield till plants were three months old (Table 4).

Table 4 General rate of vermicompost application in different crops

Crops	*Rate*
Field crops	3–5 t/ha
Vegetable crops	5–7 t/ha
Fruit crops	3–5 kg/tree
Flower crops	100 g/pot
Nursery bed and lawns	1–2 kg/m^2

3.3.2 Growth of maize corn (Zea Mays L.)

Vermicompost product from the Horticulture waste is being used for the growth of maize plant is under observation (Table 5). Corn (Zea Mays) is a widely consumed cereal crops throughout the world. It is used as a staple food for the peoples of the Tamilnadu and also contributes in animal feed. Application of chemical fertilisers help to overcome the nutrient deficiencies but excess use of these chemical fertilisers reduced the soil fertility by changing soil pH. Corn is particularly tolerant with respect to the pH of soil and it can survive in a range of pH 5.2 and 7.6, optimum corn production was reported between pH 6.5 and 7. Chemical fertilisers needs could be substitute by introducing organic fertiliser, these organic fertilisers helps in increasing crop productivity without affecting soil fertility and pH. Organic manure contains a large mass of easily fermentable organic matter. It is a prime source of major nutrients. This study was carried out to confirm the nutrient availability and maize growth in soil amended to mineral fertiliser and compost. The experiment was conducted with mineral fertiliser and compost amendment for maize crop (vermicompost collected from *E.Fetida*). The results of this study showed that compost can be used to increase maize growth and yield. It is concluded that compost can be used as a soil amendment for improving soil organic matter and available nutrients and for increasing crop production. It is prepared to supplement this work through field studies on different crops for determining its real value to the farmer.

Table 5 Cashew graft growth using vermicompost and vermiwash

Parameters	*Days after grating*					
	20	*25*	*30*	*40*	*60*	*90*
No. of leaves	4.0	5.0	7.0	9.0	11	12
Shoot height(cm)	2.6	4.0	5.5	6.6	6.8	8.7
Shoot dry matter(g)	0.05	0.07	0.11	0.18	0.29	1.5

Table 6 Growth of maize plants promoted by vermicompost and vermiwash, chemical fertiliser and control (average growth in cm)

Parameters studied	*Control*	*Chemical fertiliser (Urea and muriate of potash and mono ammonium phosphate (12:61:0) and multi-K (13:0:46)*	*Vermicompost and vermiwash*
Seed sowing	26th August 2016		
Seed germination (days)	6	7	7
Growth in 4 weeks	32	42	42
Growth in 6 weeks	44	60	58
Growth in 12 weeks	45	87	90
Growth in 15 weeks	48	87	96
Formation of new corn (16 Weeks)	None	None	New corn
Colour and texture of leaves	Pale and thin leaves	Green and stout leaves	Green, stout and broad leaves

4 Discussions

Based on the observations, it was obvious that *E.Fetida* was found to be the suitable aspirant for vermiconversion of horticultural waste than *Eudrilus Eugenia* (Figure 6 and

Table 1). In accordance with our results it was found that vermicompost is ideal organic manure for better growth of plants. Londhe and Bhosle (2015) highlighted the recycling of Solid wastes in to organic fertilisers using low cost treatment: vermi-composting. Worms and vermicompost promoted excellent growth in the vegetable crop with more flowers and fruits development. Vermi-compost increases plant growth of some vegetable crops such as tomatoes, Chinese cabbage, spinach, strawberries and lettuce (Adhikary, 2012). Vermicompost can be used for all crops agricultural, horticultural and vegetables at any stage of the crop (Figures 9 and 10). Studies made on the effects of vermicompost on Cashew grafts and maize plants it was found that growth and flower appearance were significantly higher in those plots which received vermicompost. The observed results are supported by those of other authors (Joshi et al., 2015; Kumar and Lekeshmanaswamy, 2016; Zaremanesh et al., 2017). The product from vermicomposting, also hold moisture better than plain soil and contain worm mucus which allows for the prevention of nutrients being washed away at first watering. In this way both the purpose of improved indoor climate as well as organic farming is achieved (Tables 4 and 5). Similar observations have been reported by (Mistry, 2015). The biological fertiliser 'vermicompost' is rich in NKP, micro-nutrients, beneficial soil microbe's, humus and growth hormones have been reported by (Kanimozhi and Jayakumar, 2015; Pigatin et al., 2016). Hence it may be concluded, horticultural waste decomposition by Eisenia fetida was found to be better for vermicompost than the *Eudrilus Eugenia*. Therefore it can be inferred from above result that vermicompost is today's natural fertiliser which not only increases the plant growth and productivity by nutrient supply but it also costs effective and pollution free.

Figure 9 Vermiwash tank and collected vermiwash in bucket

4.1 Feedbacks from farmers using vermicompost in Vriddachalam Taluk, Cuddalore District

Some farmers are interviewed in the Taluk using only vermicompost in crop production and completely giving up chemical agriculture. Most of them asserted that they have switched over to organic farming by vermicompost completely and eliminating the use of chemical fertilisers for the past 3–4 years. They had benefiting both, their economy (reduced cost of inputs and significantly high outputs from good crop production, sale of vermicompost and worms) and the environment (reduced use of chemical pesticides, improved physical, chemical and biological properties of farm soil). Some of them asserted to have harvested three different crops in a year (reaping 2–3 times more harvest) due to their rapid growth and maturity and reduced harvest cycle.

Figure 10 Nutrient values of vermiwash

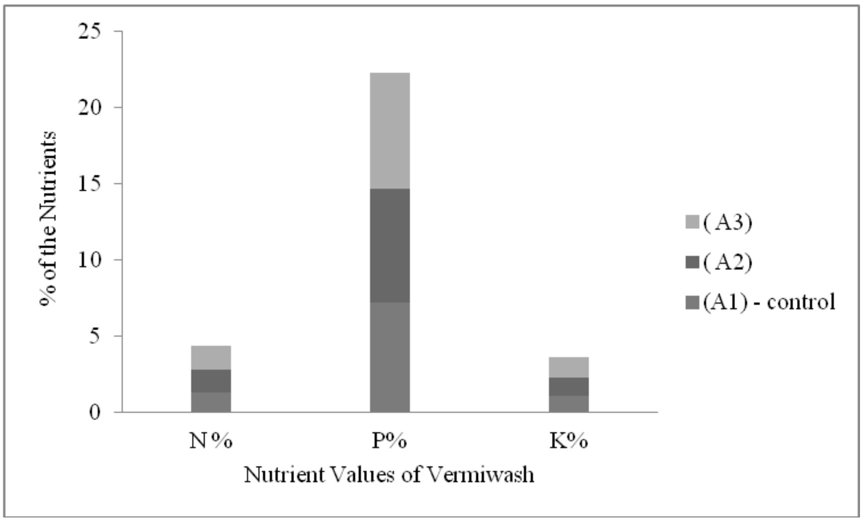


Figure 11 Applications of manure in cashew orchards for boosting production

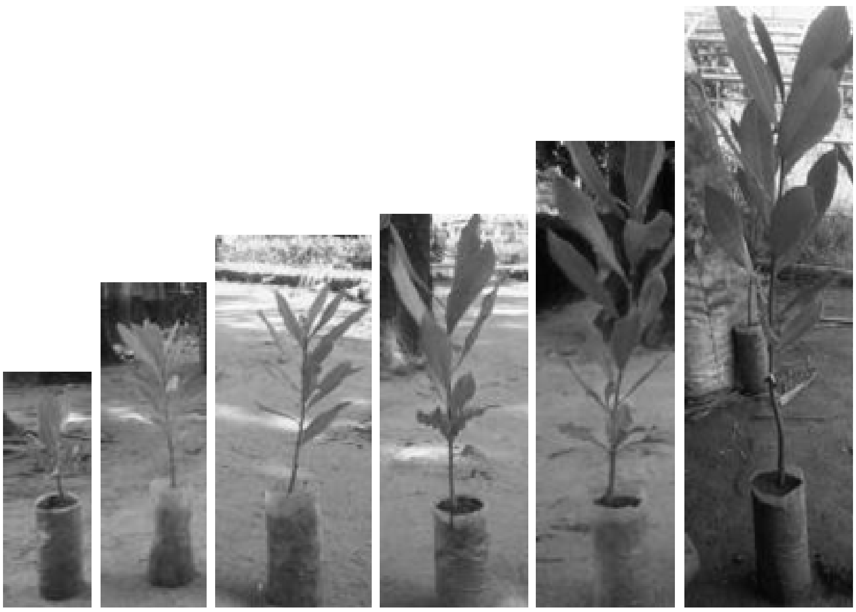


Figure 12 Variation in root growth of cashew plants at 0–3 month intervals

5 Conclusions

Vermiculture is the best way of disposing waste coming from Horticulture waste. In the present study, *E.Fetida* showed better nutrient recovery from the organic matter through efficient mineralisation. Through this process no chemicals and no reaction are needed to convert these wastes into manure. On analysis of the data the following conclusions are made; the results from the vermicompost analysis had revealed that the Horticulture waste can be converted into usable form with its nutrient release. The compost which is rich in microorganism enhances the plant growth hormones. This is an eco friendly and cost effective method. It is an ideal method for the management of solid waste. To conclude that vermicomposting plays a significant role in protecting environment as it uses waste as raw material and in building up of soil fertility and improving soil health for sustainable agriculture.

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